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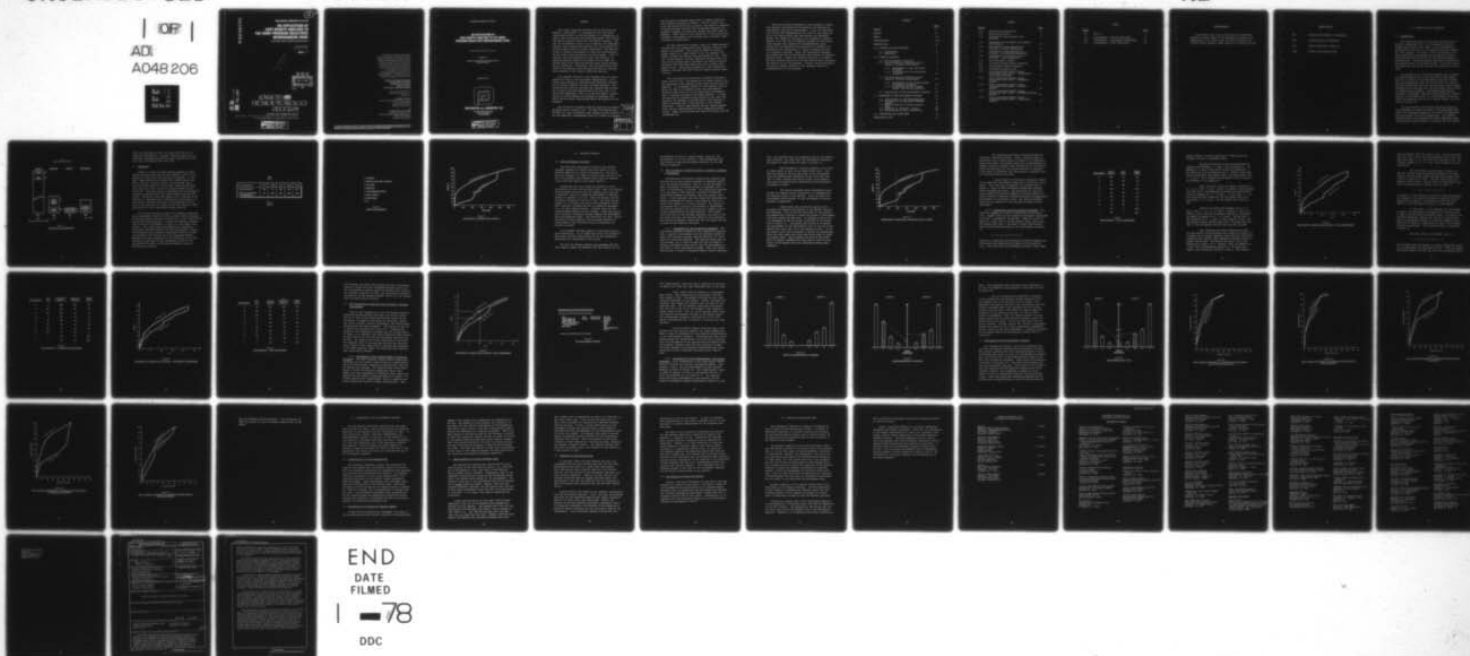
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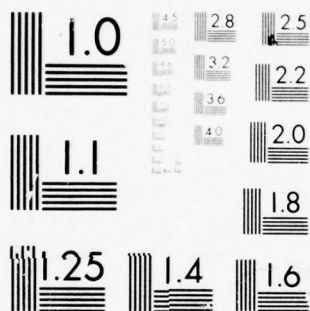
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TECHNICAL REPORT 77-8-72

AN APPLICATION OF COST-BENEFIT ANALYSIS TO THE USMC PROGRAM OBJECTIVES MEMORANDUM (POM)

DECISIONS AND DESIGNS INCORPORATED

Dennis M. Buede
Cameron R. Peterson

NOV. 1977

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TECHNICAL REPORT TR 77-8-72

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COST-BENEFIT ANALYSIS TO THE USMC
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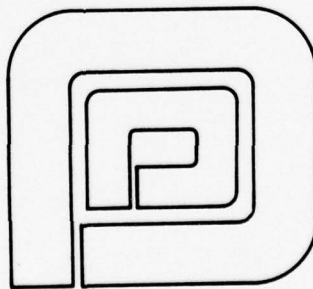
by

Dennis M. Buede and Cameron R. Peterson

Prepared for

Defense Advanced Research Projects Agency
ARPA Order 3052

November 1977



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SUMMARY

This report describes the work done by Decisions and Designs, Incorporated, in collaboration with the United States Marine Corps, on the development of a methodology to improve the 1979 Program Objectives Memorandum (POM) process. The generic approach chosen was cost-benefit analysis. The goal of cost-benefit analysis is to identify, for subsequent funding, those programs that optimize the total benefit to a decision maker within his budget constraints. The identification of optimal procurements is based upon determination of the "true" costs and benefits of each program. "True" or absolute costs and benefits are often very difficult to determine because subjective estimates must be made, and because some of the less-than-obvious costs and/or benefits may be overlooked. Fortunately, for this application estimates of the absolute costs and benefits were not required, only estimates of the relative costs and benefits.

The programs involved in this analysis were all future capability items in the procurement appropriation. DDI's efforts were focused on obtaining good subjective estimates of the relative benefits for each of these programs. Psychologists and decision analysts have observed that the best way to obtain accurate quantifications of this sort is to use paired comparisons, that is, to ask the expert to make a series of choices between two packages of programs, each choice having certain implications about the benefits of the programs.

The elicitation procedure used for obtaining the benefit estimates was an iterative one. The USMC POM programs were divided into eight categories, each category having a sponsor who was especially knowledgeable about his subset of programs.

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The elicitation procedure began with an ordinal listing of each sponsor's programs by benefit. Once an initial ratio scale was defined over these programs, the sponsor's responses to choices between numerous sets of programs generated the feedback necessary to modify and improve this ratio scale of benefits. After three or four iterations of this elicitation procedure, each sponsor was satisfied that his benefit scale reflected his preferences.

The next step was to convene a group of "honest-brokers," officers from the Headquarters Staff sections, which do not sponsor any programs. This group was asked to provide a benefit scale for a small subset of all the programs; the subset included one program from each sponsor's list. After the "honest-brokers" had been completely educated about the uses of the programs being considered, the same elicitation procedure--that described above--was used to obtain their benefit scale. This scale provided all of the information needed to collapse the eight distinct sponsor benefit scales into one.

This cross-sponsor elicitation of benefits provided a proper scoring rule. The meaning of the proper scoring rule was explained to each sponsor in the course of eliciting his benefits: If the sponsor ranked the lower-benefit procurements too high on his benefit scale, the cross-sponsor weighting would drag all of his high-benefit procurements down in relation to those of the other sponsors. A proper scoring rule for subjective elicitations of this sort thus motivates the sponsors to provide their "true" beliefs in order to maximize their final position in the resource allocation. Finally, each sponsor and the "honest-brokers" wrote concise justifications of their respective benefit scales. These justifications were used for briefing the POM recommendations.

There were several advantages to the systematic, exhaustive analysis that generated the benefits and produced the cost-benefit ordering of procurements. First, the justification for the POM recommendations was right at the fingertips of the POM working group when the analysis was completed. Second, the "hands-on" availability of interactive computer software on an IBM 5100 minicomputer allowed the POM working group charged with preparing the recommendations great flexibility for evaluating the sensitivity of benefits and determining the implications of funding programs that were not originally included. Third, the cost-benefit approach facilitated the rapid identification and solution of important decision areas. Fourth, the analysis resulted in a general but more thorough education of the POM working group concerning the benefits of all the programs. Finally, future POM efforts are going to benefit because of the corporate memory and transferability of this process.

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ACKNOWLEDGMENT

This research was jointly supported by the Advanced Research Projects Agency of the Department of Defense and Headquarters, U.S. Marine Corps and was monitored by the Office of Naval Research under Contract No. N00014-76-C-0074.

ABBREVIATIONS

DDI	Decisions and Designs, Incorporated
POM	Program Objective Memorandum
TOA	Total Obligational Authority
USMC	United States Marine Corps

1.0 INTRODUCTION AND BACKGROUND

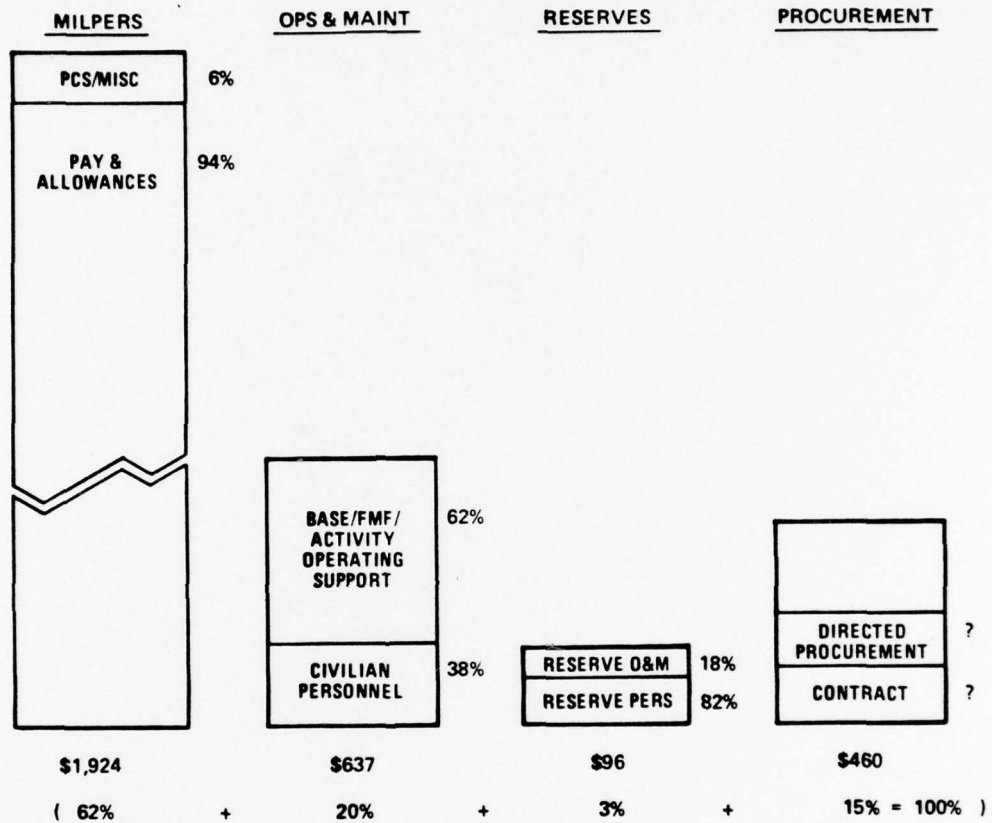
1.1 Introduction

This report describes the work done by Decisions and Designs, Incorporated (DDI), in collaboration with the United States Marine Corps (USMC), on the development of methodology to improve the 1979 Program Objectives Memorandum (POM) process. The first of the four sections in the report describes the background of the specific problem. The technical work done by DDI for the POM development is presented next. The third section describes the benefits of the research effort to the Marine Corps. The fourth section discusses important future work and also serves as a conclusion.

The purpose of this application project was to develop an improved methodology to help the Marine Corps prepare part of its portion of the Department of the Navy Program Objectives Memorandum (POM) for the 1979-1983 time period. The 1979 program year was most crucial since it would almost immediately be translated into the 1979 budget and be subject to defense before Congress. The appropriation dollars available for manpower, operations and maintenance, reserves, and part of procurement are, to a large degree, relatively fixed and constitute over 90% of a typical budget, as illustrated in Figure 1-1.

The most flexible and difficult decisions concerning the programming of funds are found in the procurement area, which, for programming purposes, is divided into ammunition and both current and future capabilities. Our analysis centered around the procurement of future capability items. The projected funding profile in this area for 1979 through

FY-78
TOTAL TOA - \$3,117 (\$M)*



*Does not include stock fund (\$2.0M)

Figure 1-1
GREEN DOLLAR DISTRIBUTION

1983 is illustrated in Table 1-1 along with the costs of validated requirements. As shown, there are some years in which the requirements exceed the total obligational authority (TOA) available by more than 200%.

1.2 Background

Figure 1-2 lists the eight program sponsors at Headquarters Marine Corps, each of whom sponsors various future capability items; each item has only one sponsor. In the past, these sponsors have entered the "smoke-filled" room with an ordinal listing of their own procurement items. Each would then agree to give up their least desired items until the total costs for the five years matched the projected TOA. This was clearly a suboptimal and non-systematic procedure, adapted from a Navy POM procedure with the same traits. The Marine Corps was unhappy with it because it was difficult to determine which items would be eliminated if a last-minute insertion were made, how adjustments would be made if the costs were to change at the last minute, or what the effects of other last-minute changes might be.

DDI analysts pointed out that this procedure determined which procurements should be made by a benefit-only criterion within each sponsor and that it permitted no clear trade-offs of the benefits among sponsors. A simple cost-benefit analysis, such as the one illustrated in Figure 1-3, was clearly more optimal. This figure shows the hypothetical purchase of items based upon both benefit-only and cost-benefit criteria. The horizontal axis represents accumulated dollars as items are purchased, the vertical axis the accumulated benefit. Whenever the fiscal constraint is as restrictive as the one the Marine Corps faced in the development of POM 79, the cost-benefit criterion yields greater benefits than the benefit-only criterion.

PMC
(SM 78)

<i>Future Capabilities:</i>	FY 79	FY 80	FY 81	FY 82	FY 83
TOA AVAILABLE	106	75	106	215	271
COST OF VALIDATED REQUIREMENTS	181	286	325	306	253

Table 1-1
POM 79

- TRAINING
- INSTALLATION AND LOGISTICS
- AVIATION
- RESERVES
- TELECOMMUNICATIONS
- INTELLIGENCE
- OPERATIONS
- C⁴

Figure 1-2
MARINE POM SPONSORS

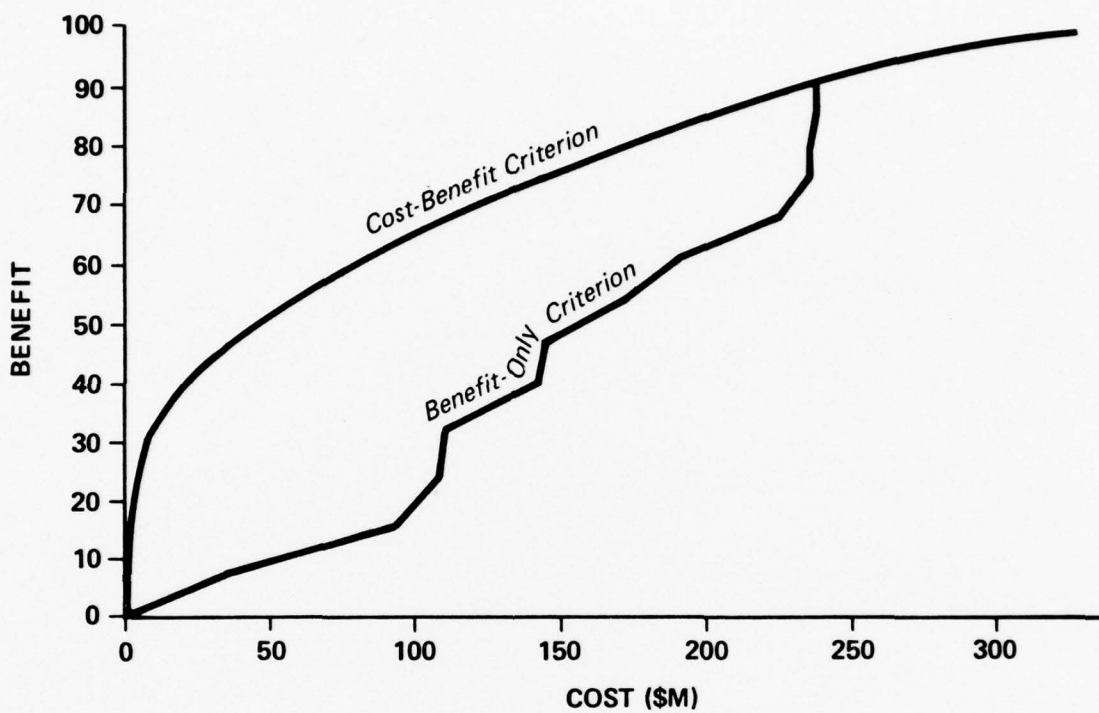


Figure 1-3
COST-BENEFIT VS. BENEFIT-ONLY CRITERIA

2.0 TECHNICAL APPROACH

2.1 The Cost-Benefit Criterion

The well-known cost-benefit criterion for choosing programs attempts to optimize the total benefit to the decision maker for any level of expenditure. This could mean the purchase of a number of options that are not at the top of the benefit scale because their costs are substantially less than options with higher benefits.

Determining the "true" costs and benefits of each alternative can be a very difficult task. Take, for instance, the government directive that all agencies are to use the "life-cycle" costs of a potential procurement in deciding whether to purchase it or not. There are obvious and not-so-obvious elements of life-cycle cost: The first obvious element is, of course, the cost of the procurement itself, which typically includes the cost of supporting equipment, e.g., all guns require bullets. Training costs for the procured system should also be included. Other less obvious costs typically considered include research and development costs and operating costs. But where does one stop? Should the costs of naval hospitals and retirement benefits be proportioned to the life-cycle costs of submarines and aircraft carriers?

Still another difficult aspect of life-cycle costs is their uncertainty. All of these costs are to be incurred in the future, and thus they contain all of the uncertainty associated with projections of the future.

The next two sections discuss the procedures DDI analysts used to assess the benefits from each sponsor for his

procurements and from an "honest-broker" group for the procurements of all the sponsors. These assessments were facilitated by specially-programmed software for the IBM 5100 mini-computer.

2.2 The Elicitation of Benefits Within a Sponsor's Proposed Procurements

Psychologists and decision analysts have observed that the best way to get reliable estimates of potential benefit is to use paired comparisons, that is, to ask the expert to make a succession of choices between two packages until a point of indifference is reached. The conventional approach is to use money as the numeraire attribute to establish indifference between two bundles, each with several attributes. In that approach, once the expert has established an ordinal preference for bundle A over bundle B, say, he is asked if he prefers A or B plus X dollars. The value of X is adjusted until a point of indifference is established. The relation between B and the status quo, neither A nor B, is then established by the same procedure. This method works very well in the business community, but since it has not fared very well with decision makers in the government, DDI analysts developed a method that did not require the use of money as the numeraire attribute.

2.2.1 Development of the elicitation procedure - The elicitation procedure devised for this application required that a sponsor's procurements first be ordinally ranked by their total benefits and then assigned directly to a ratio scale for individual benefits. The resulting scale was not too reliable, but it could be used with the cost data to compute cost-benefit ratios and to rank the procurements in the order in which they would be bought. Then, two curves were plotted in terms of cumulative benefit versus cumulative

cost, one resulting from the incremental buys by the benefit-only criterion, the other using the cost-benefit criterion. An example of these curves are shown in Figure 2-1.

The cost-benefit criterion produces a curve that is always above or equal to the benefit-only curve. Note that the slopes of the straight lines in the cost-benefit curve are monotonically decreasing as the curve goes from left to right, whereas the vertical jumps in the benefit-only curve are monotonically decreasing as each succeeding procurement is made.

The curves illustrate which procurements would be made for numerous fiscal constraints, as represented by the numerical scale on the abscissa. Here, we assume the procurements are divisible, so that procurement of partial programs is meaningful.

These curves also provide the sponsor with a procedure for checking the accuracy of the benefit scale he has specified. This is done by using both the cost-benefit and benefit-only criteria to select two groups of procurements that have roughly the same cost. An example of such a pair is represented by the two groups to the left of the dotted line in Figure 2-1. The sponsor must decide if he prefers the procurements on the cost-benefit curve to the one on the benefit-only curve and, if so, by roughly how much. If not, the benefit scale can be adjusted to reflect his preferences. There are other equal-cost lines that can be drawn to check the benefit scale. This procedure was used at the global level of benefit judgments but could also be used at lower levels if the sponsor were more comfortable making these judgments.

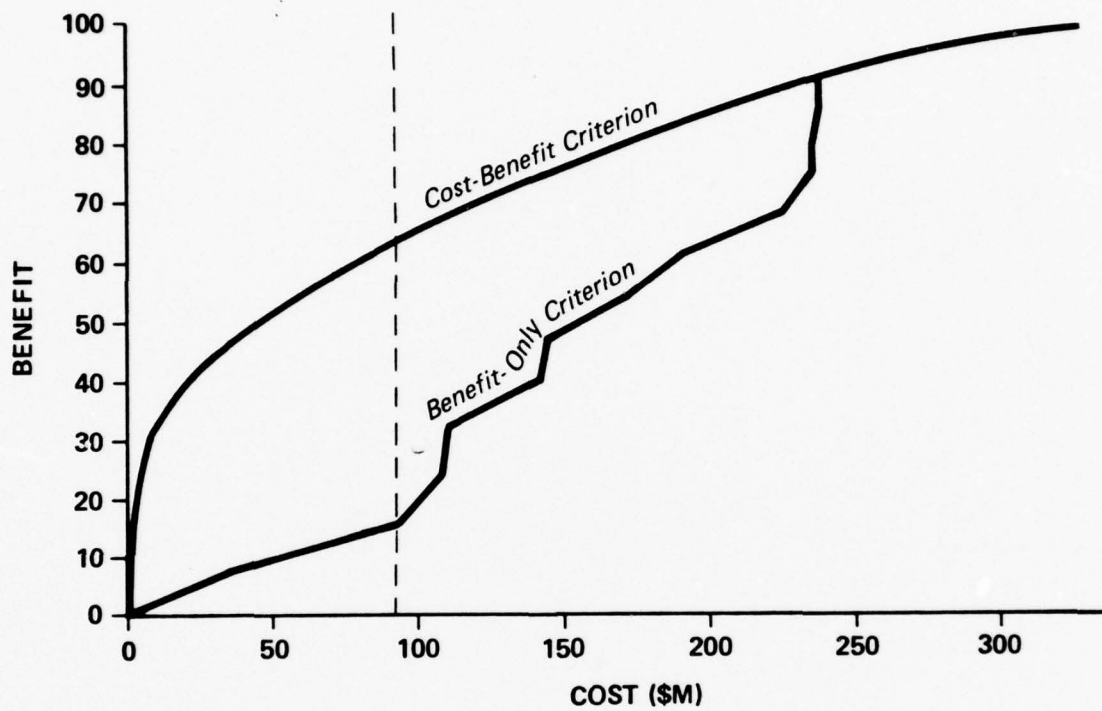


Figure 2-1
COMPARISON OF COST-BENEFIT AND BENEFIT-ONLY CRITERIA

The foregoing elicitation process dictated the following iterative procedure: First, a benefit scale is postulated, and a figure similar to Figure 2-1 is generated. Using this figure, the sponsor checks for inconsistencies at numerous levels of funding; then the benefits of the procurements are adjusted until the inconsistencies are resolved. A new figure is generated, and the process is repeated until no inconsistencies can be found.

A large number of alternative consistency checks can be made with this benefit scale since it must be a ratio scale. (Note that zero corresponds to a program with no benefit.) Many of these consistency checks were examined before accepting the scale. The application of this technique produced the stimulus needed to force the sponsor to insert realistic numerical differences between the appropriate procurements on his benefit scale. The resulting benefit scale was far superior to any generated by direct scaling techniques.

2.2.2 Illustration of the elicitation procedure - The following example is a useful illustration of this procedure. Suppose there are ten possible procurements, designated A through J, proposed by the sponsor. These are listed in Table 2-1, along with an initial benefit scale, total cost, and benefit/cost ratio. The order in which these procurements would be made according to the cost-benefit criterion is

J, I, D, A, F, E, G, H, G, C.

Figure 2-2 illustrates the difference in benefit between the cost-benefit and benefit-only criteria for all levels of cost. Note that using the cost-benefit criterion with these

<u>PROCUREMENTS</u>	<u>INITIAL BENEFITS</u>	<u>TOTAL COSTS</u>	<u>BENEFIT COST</u>
A	100	16	6.2
B	99	36	2.8
C	95	56	1.7
D	90	9	10.0
E	87	30	2.9
F	83	20	4.2
G	70	35	2.0
H	70	26	2.7
I	60	2	30.0
J	55	1	55.0

Table 2-1
PROCUREMENTS – INITIAL COMPARISONS

benefit numbers is almost equivalent to ordering the procurements by cost in descending order.

The second iteration of this process begins by comparing procurements J, I, and D with procurement A. The package J, I, and D costs nearly as much as procurement A but should be twice as beneficial as A. However, when asked which he preferred, the sponsor said A had more benefit than J, I, and D. So A's benefit was adjusted to 250 to reflect the strength of his preference.

Next, note that A and B are nearly equivalent to J, I, D, A, and F in cost. Since A is common to both packages and there are no interdependencies between the procurements, B can be compared to J, I, D, and F. In this case, J, I, D, and F were strongly preferred, and the sponsor felt B was equivalent to J, I, and D. So B's benefit was raised to 215.

The next two equal-cost packages are A, B, C, and D, and J, I, D, A, F, E, and B. Since A, B, and D are common to both, they can be deleted; therefore, the sponsor was asked to compare C to J, I, F, and E. He felt that C was equivalent to J, I, and F or had a benefit of 205. The new benefit numbers implied that B and C are more beneficial than A, and the sponsor verified that this was the case.

This exhausted the useful comparisons between the cost-benefit and the benefit-only criteria in Figure 2-2. A sizable gap in benefit between A and B had been identified, suggesting that several other comparisons should be made to expose similar gaps. The sponsor felt that C and D were preferred to either B or A. However, since the benefits of D and E were considered equivalent to C, ten units were added to the preliminary values of D and E. This required

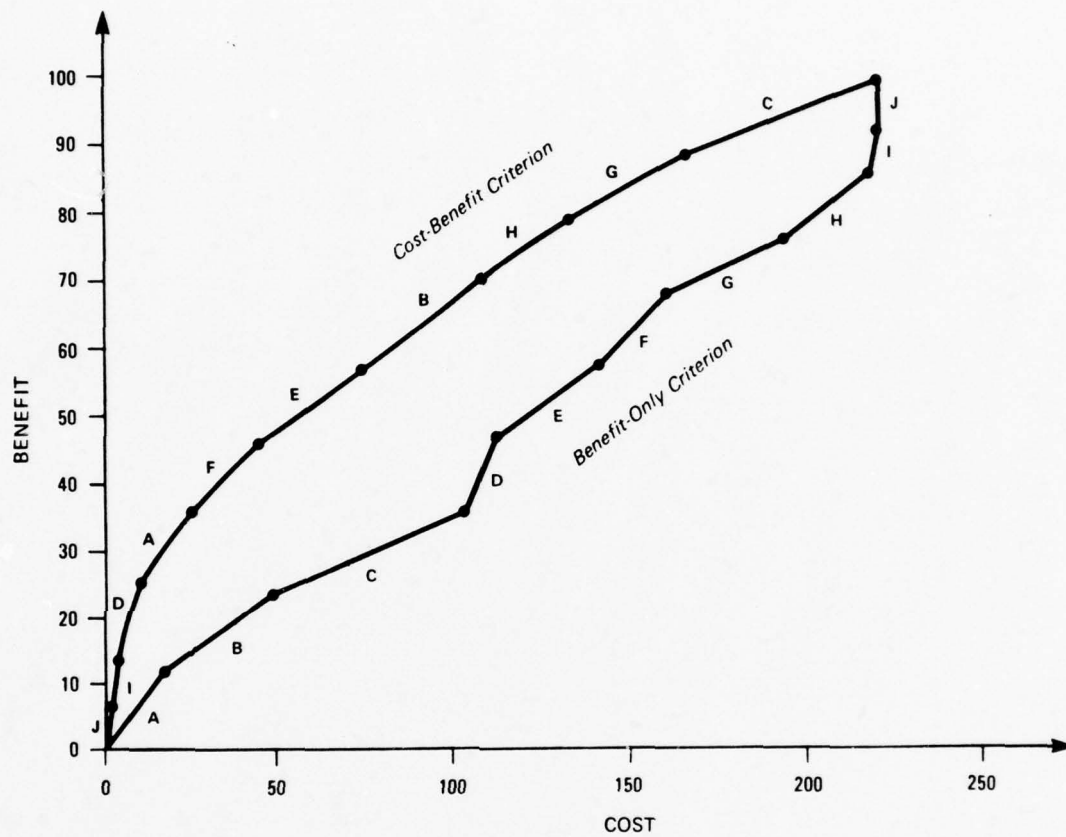


Figure 2-2
COST-BENEFIT VS. BENEFIT-ONLY CRITERIA – INITIAL COMPARISONS

that B's benefit value be raised to 225. The decision maker also felt that E and F were more beneficial than D but less beneficial than C. So, the value of F was kept at 83. The original numbers for G, H, I, and J were thought to be representative.

The new benefits are displayed in Table 2-2. The third column gives the benefits assigned in the above process, and the fourth column displays the benefits normalized to a zero-to-100 scale. The last column shows the benefit-to-cost ratios. The new order of cost-benefit buys, which is substantially different than the first, is

J, I, A, D, B, F, C, E, H, G.

In Figure 2-3, the cumulative benefits of these procurements are compared to the cumulative benefits resulting from the benefit-only criterion. Now benefit and cost are equal factors in the cost-benefit ordering of procurements.

At this point, it was necessary for the sponsor to explain to his experts and superiors the choices he had to make in deriving this new benefit scale. In doing so, he uncovered additional factors that led him to move procurement G up the benefit ladder to a position between C and D. Through this iterative, comparative process, a final benefit scale was constructed. This normalized scale is presented in Table 2-3.

The final order of cost-benefit buys is

J, I, D, A, B, G, F, C, E, H.

This process helped the sponsor to develop substantive rationale for supporting the final benefit scale. Since the sponsor had worked closely with both his superiors and experts during

<u>PROCUREMENTS</u>	<u>COSTS (\$)</u>	<u>INTERMEDIATE BENEFITS</u>	<u>NORMALIZED BENEFITS</u>	<u>BENEFIT COST</u>
A	16	250	100	6.2
B	36	225	90	2.5
C	56	205	82	1.5
D	9	105	42	4.7
E	30	100	40	1.3
F	20	83	33	1.6
G	35	70	28	0.8
H	26	70	28	1.1
I	2	60	24	12.0
J	1	55	22	22.0

Table 2-2
PROCUREMENTS – INTERMEDIATE COMPARISONS

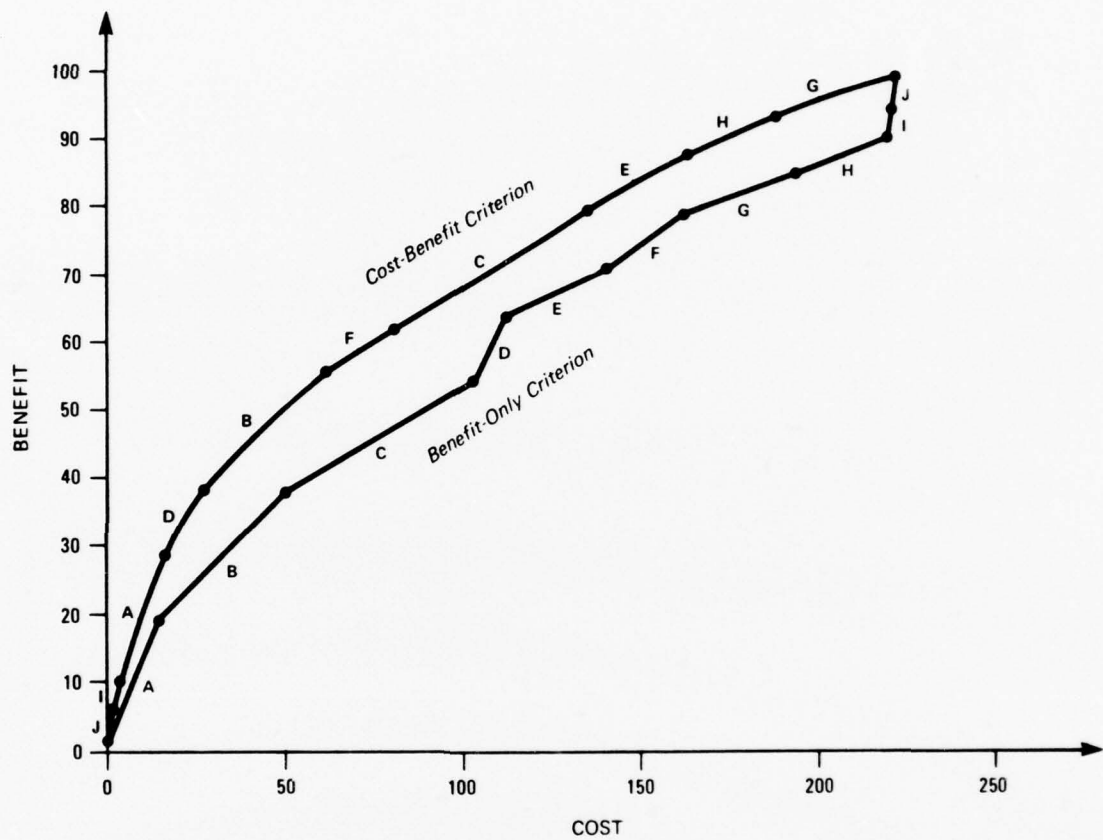


Figure 2-3
COST-BENEFIT VS. BENEFIT-ONLY CRITERIA – INTERMEDIATE COMPARISONS

<u>PROCUREMENTS</u>	<u>COSTS (\$)</u>	<u>ORIGINAL BENEFITS</u>	<u>FINAL (NORMALIZED) BENEFITS</u>	<u>BENEFIT COST</u>
A	16	100	100	6.2
B	36	99	83	2.3
C	56	95	80	1.4
G	35	70	72	2.1
D	9	90	58	6.4
E	30	87	37	1.2
F	20	83	30	1.5
H	26	70	19	0.7
I	2	60	15	7.5
J	1	55	8	8.0

Table 2-3
PROCUREMENTS – FINAL COMPARISONS

this process, the scale and rationale had their concurrence. Figure 2-4 shows the final differences between buying with the cost-benefit criterion versus the benefit-only criterion. For a fiscal constraint of \$100, the cost-benefit criterion provides 68% of the possible benefit, which is a 33% increase over the benefit-only criterion.

2.3 The Elicitation of Benefits Across Sponsors' Proposed Procurements

Prior to the introduction of the cost-benefit approach, trade-offs across sponsors were made in an ad hoc manner. The use of this ad hoc method was dictated largely by the difficulty of comparing such things as howitzers, command and control systems, reserve procurements, and sophisticated communication and radar equipment. (The essence of the POM 79 problem is illustrated in Figure 2-5.) Nevertheless, because of the diversity of programs and the limited amount of funds, it is important that these trade-offs among sponsors be made explicit so that rational procurement decisions can be made. For example, one of the conclusions of the trade-off procedure used in this analysis was that the logistics area, because of the acquisition of sophisticated equipment in the other sponsors' areas, was relatively more important than traditionally thought.

2.3.1 Development of the "honest-broker" elicitation procedure - The eight different sponsor benefit scales were collapsed into one benefit scale by using an "honest-broker" group of Marines from Headquarters staff sections, which do not sponsor any programs. The "honest-broker" group represented a variety of military occupational skills; each member was given comprehensive information about items to be compared and was asked to study the material in detail. To further educate this "honest-broker" group, a question-and-answer session was held with sponsor participation. Here,

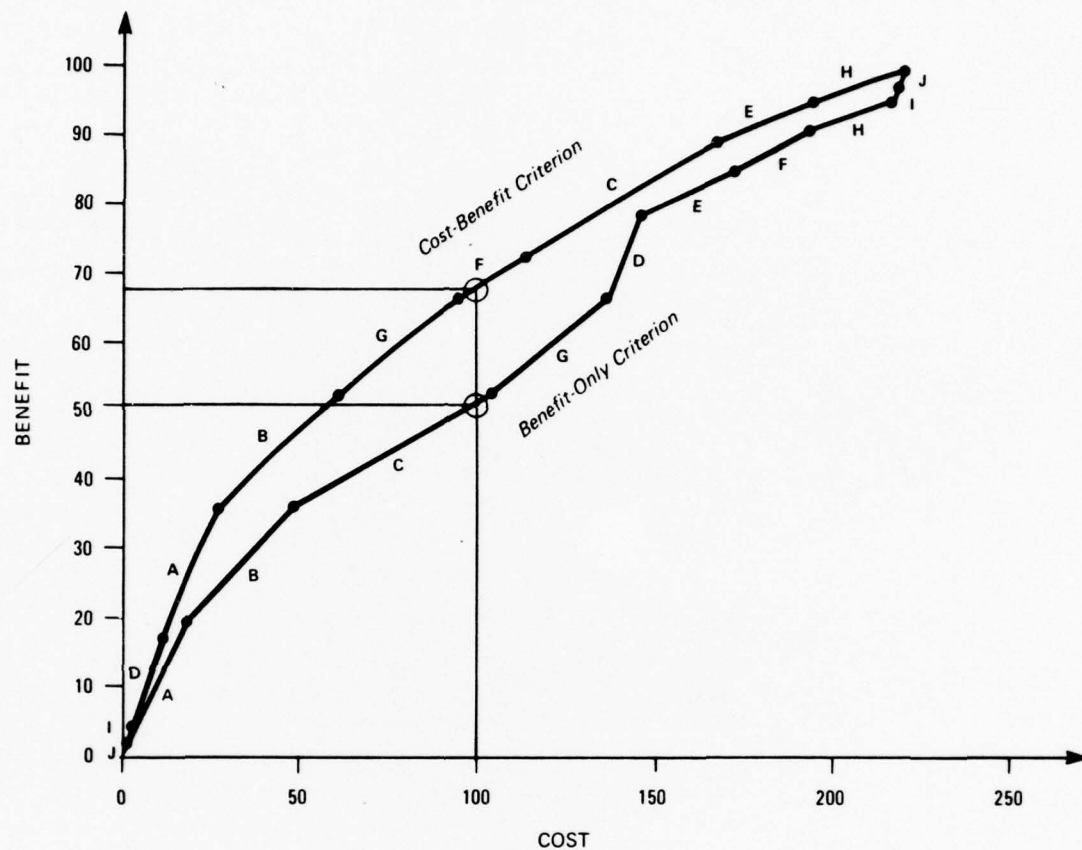


Figure 2-4
COST-BENEFIT VS. BENEFIT-ONLY CRITERIA: FINAL COMPARISONS

MODERNIZATION (FUTURE CAPABILITIES)

Allocate Limited TOA Among Such Things As:

MULE	PLRS	RES ARTY BN	AN/UYQ-4
XM198 155MM HOW	MIFASS	RES TANK CO	AN/TPS-59
XM204 105MM HOW			MACCS-85
NIGHT VISION GOGGLES			TSC-85
LT WHT CO MORTAR			TSC-93
XM-1 TANK			PSC-1
			VINSON INSTALL KIT
			TYA()

- *And Almost 100 More Similar Proposals*

Figure 2-5
THE PROCUREMENT PROBLEM

the "honest-broker" group was able to question the sponsors in detail until they felt they understood each of the items.

First, three distinct packages of procurements were formed. Each package had one procurement item from each sponsor's list. One package contained the most beneficial procurements of each sponsor. Another contained procurements that needed 1979 funding since this was the most important year. The two packages containing procurements that were not at the top of the sponsors' lists served as proper scoring rules. That is, if the sponsor ranked these lower-benefit procurements too high on his benefit scale, the cross-sponsor weighting would drag all of his high-benefit procurements down in relation to those of the other sponsors.

This elicitation process could have been accomplished with only one such package, but three packages were used in order to compensate for some expected inconsistencies in the cross-sponsor judgments. Inconsistencies were anticipated because the "honest-broker" group was not as familiar with the procurements as the sponsors were and because these cross-sponsor judgments were much more difficult to make. The three packages of procurements highlighted these inconsistencies so that intelligent discussion could resolve them.

2.3.2 Illustration of the "honest-broker" elicitation procedure - As an illustration of the cross-sponsor benefit scaling, consider the following two-sponsor example. Each sponsor, A and B, has four procurements and has assigned benefits as shown in Figure 2-6. The "honest-broker" group is asked to compare A-2 and B-3, and decides that B-3 is twice as beneficial as A-2 (Figure 2-7). (In practice, there were eight procurements in each package, and the iterative assessment procedure described in Section 2.2 was

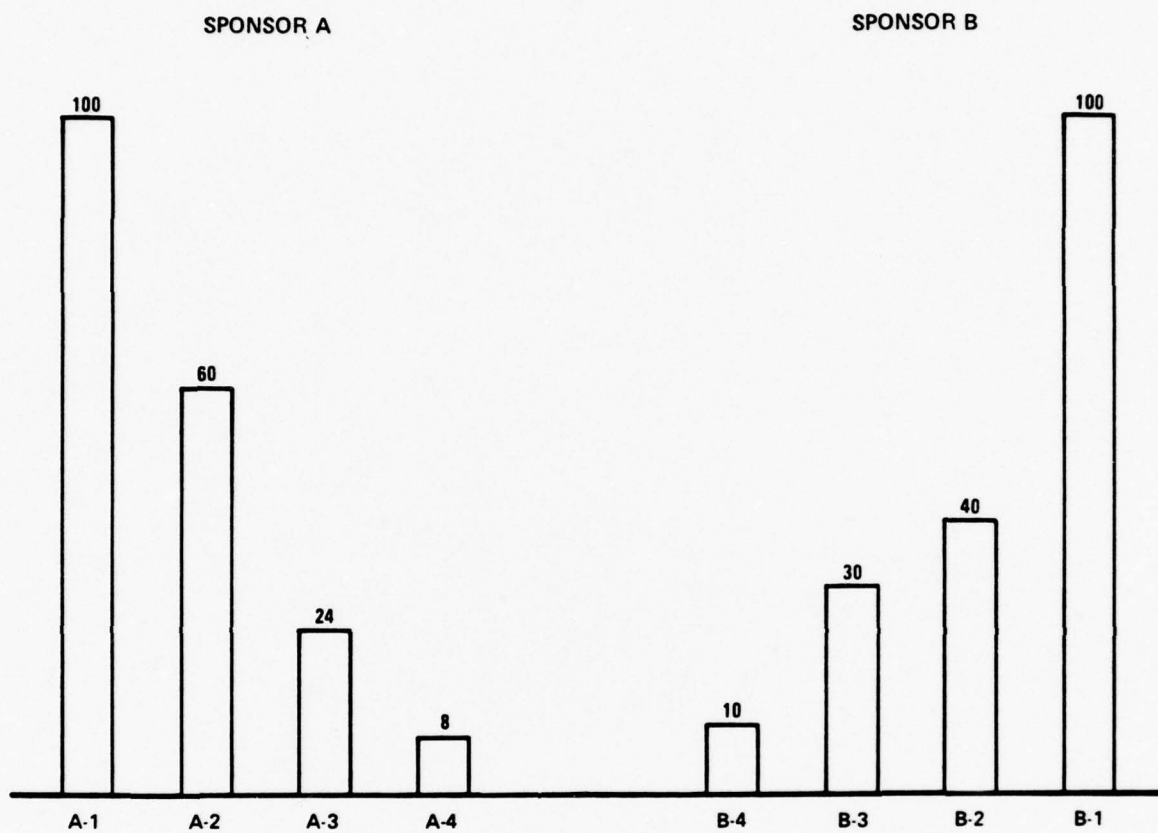


Figure 2-6
INDIVIDUAL SPONSOR BENEFIT RANKINGS

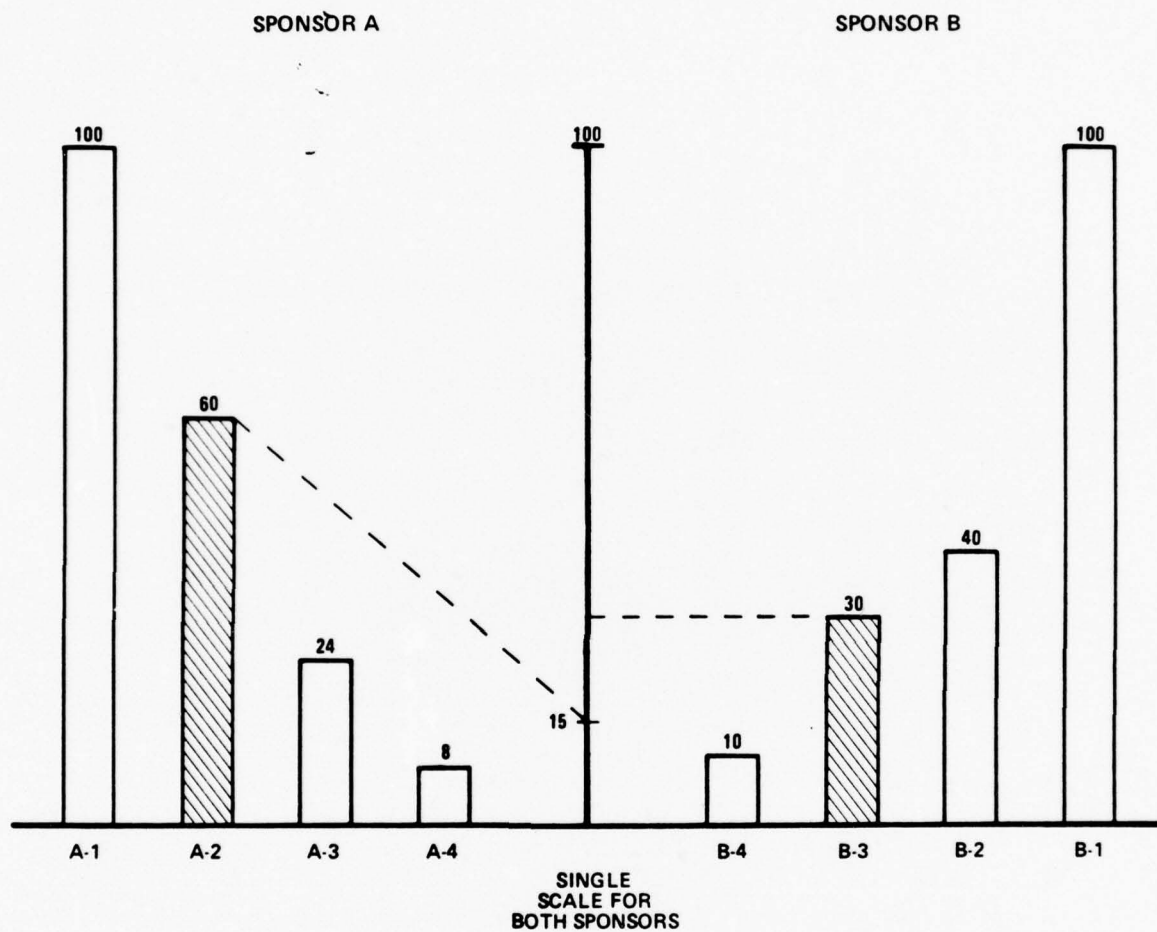


Figure 2-7
CROSS-SPONSOR BENEFIT RANKINGS

used.) This assessment then provides enough information to put the procurements of both sponsors on one scale as shown in Figure 2-8.

For this cross-sponsor assessment of benefits, it was assumed that the sponsor's benefit rankings of his own programs were valid and could not be changed. This assumption was made in the belief that the sponsors had more intimate knowledge about their programs than the "honest-broker" group and that it was easier to compare those procurements in one sponsor's area than in a set of cross-sponsor procurements. After the "honest brokers" provided benefit scales for the three distinct packages, several inconsistencies were noted. All but one were very minor and easily resolved. The most serious one involved a discrepancy between the results of two of the cross-sponsor assessments and the results of the third assessment. A lengthy discussion of the reasons behind the inconsistency finally led to a resolution.

2.4 Implications of the Cost-Benefit Analysis

As a comparative exercise, and on the assumption that cost data and benefit estimates were sufficiently accurate, DDI analysts generated the final accumulated-benefit versus accumulated-cost curves by using the cost-benefit and benefit-only criteria for five of the eight sponsors, based on the best cost information available. These curves are presented in Figures 2-9 through 2-13. The other three sponsors had only one procurement item each. The curves for the Installation and Logistics and the Operations sponsors were close together; however, the differences in benefit at given levels of cost are deceptively large for curves with these slopes. There are significant differences between the two curves over an extended range of cost for both the Aviation

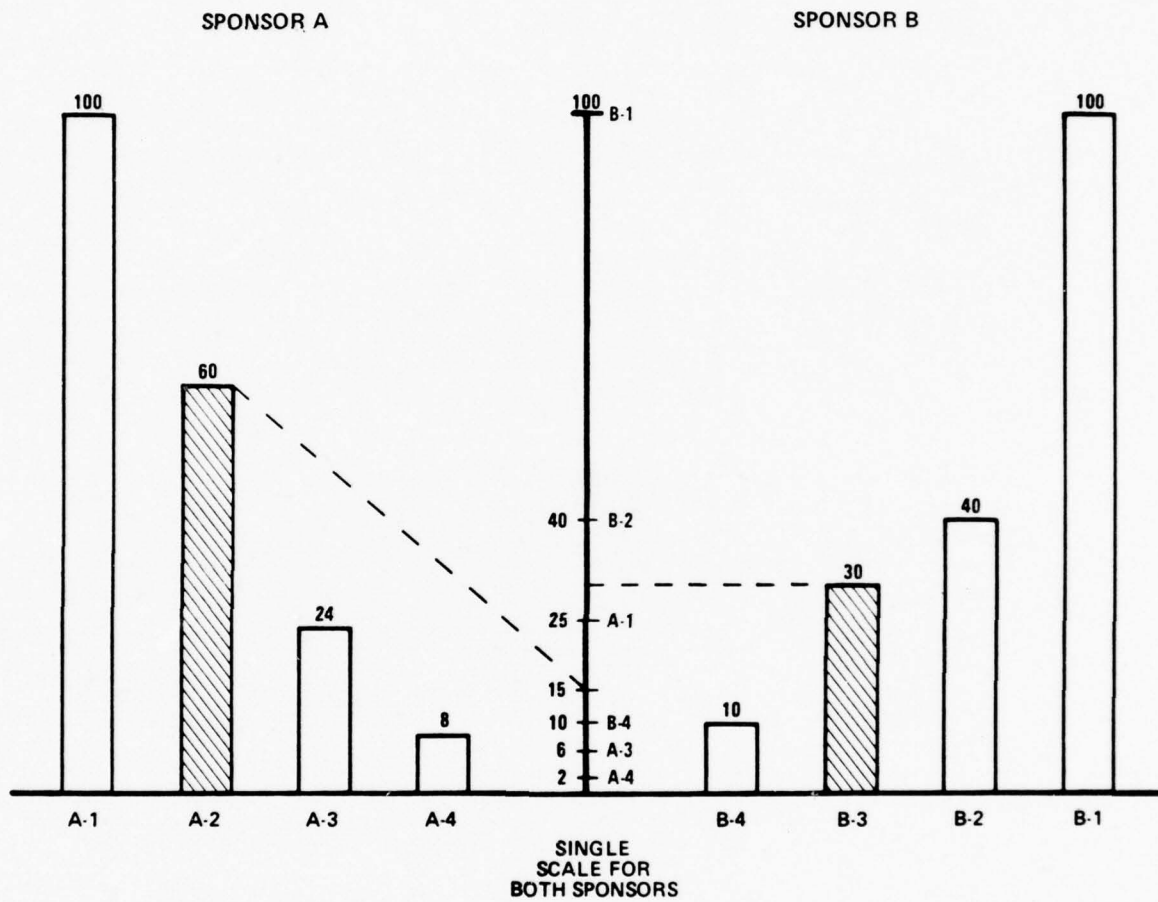


Figure 2-8
TWO-SPONSOR BENEFIT SCALE

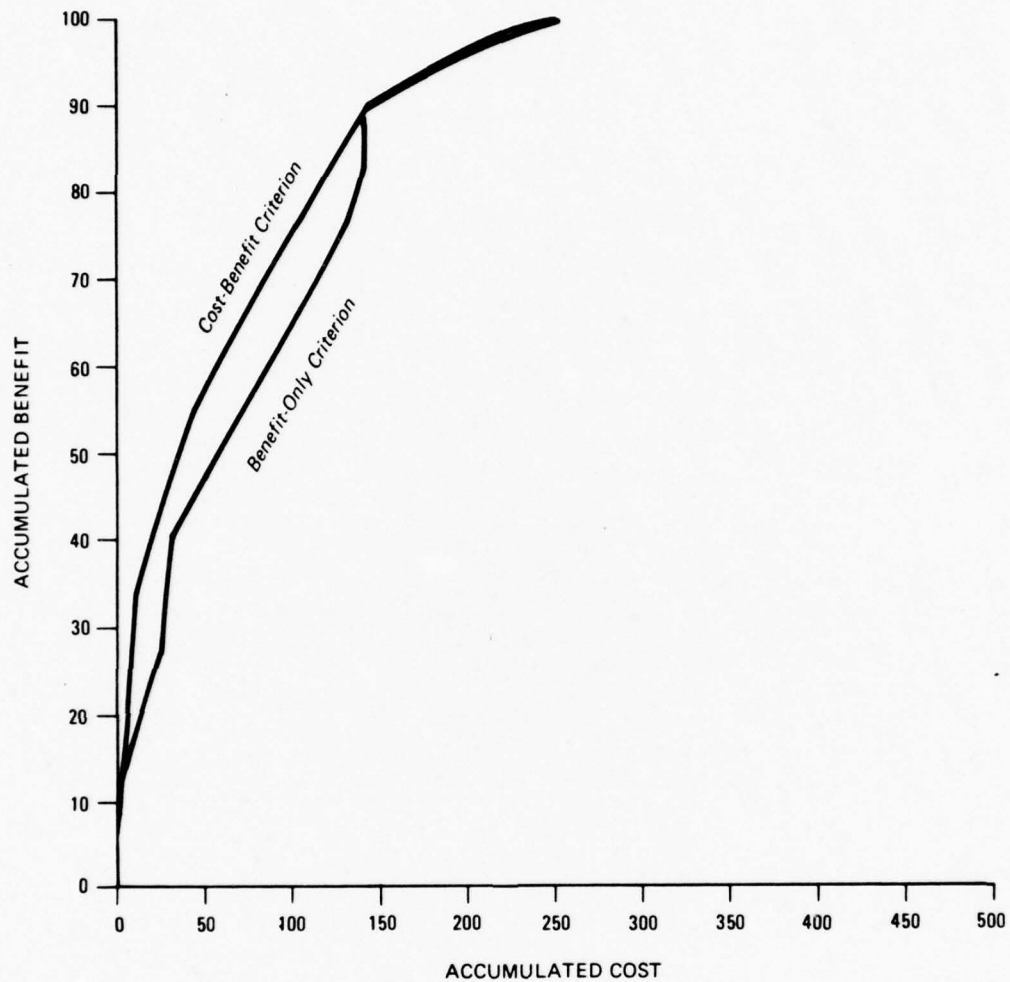


Figure 2-9
FINAL ACCUMULATED BENEFIT VS. ACCUMULATED COST CURVES –
INSTALLATION AND LOGISTICS SPONSOR

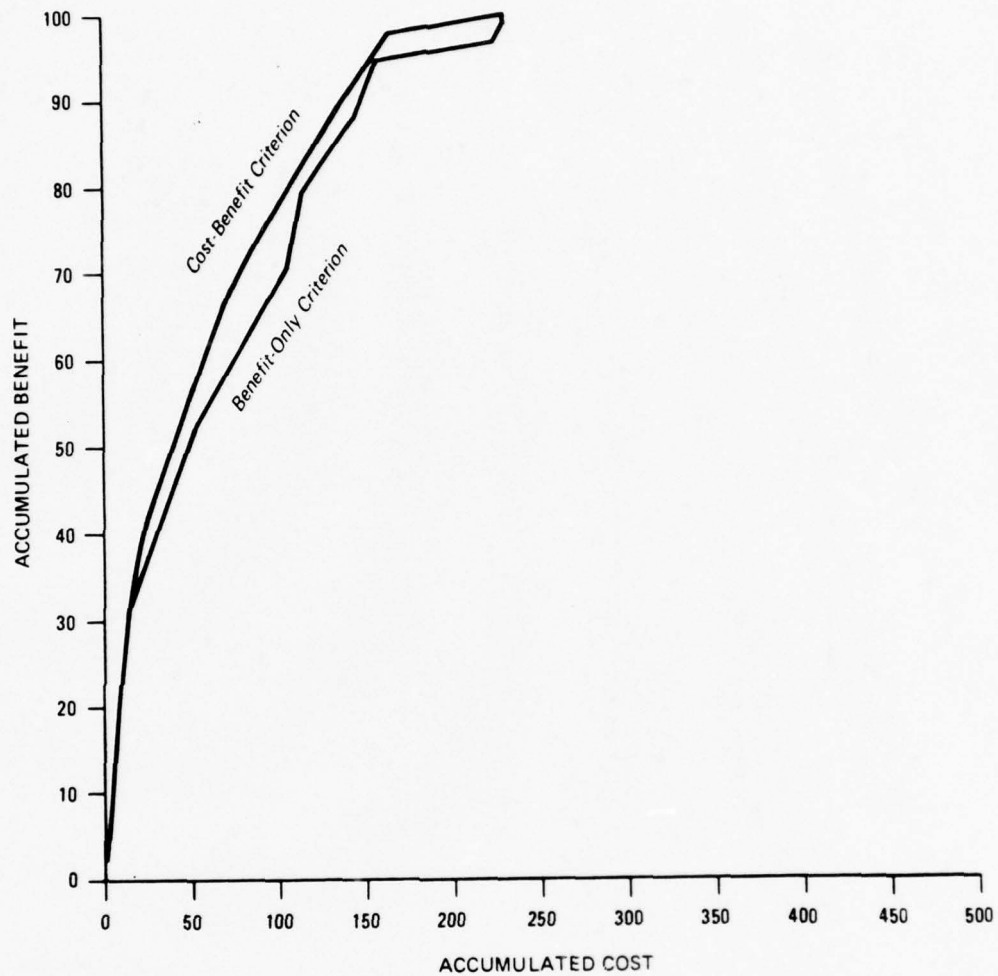


Figure 2-10
FINAL ACCUMULATED BENEFIT VS. ACCUMULATED COST CURVES—
OPERATIONS SPONSOR

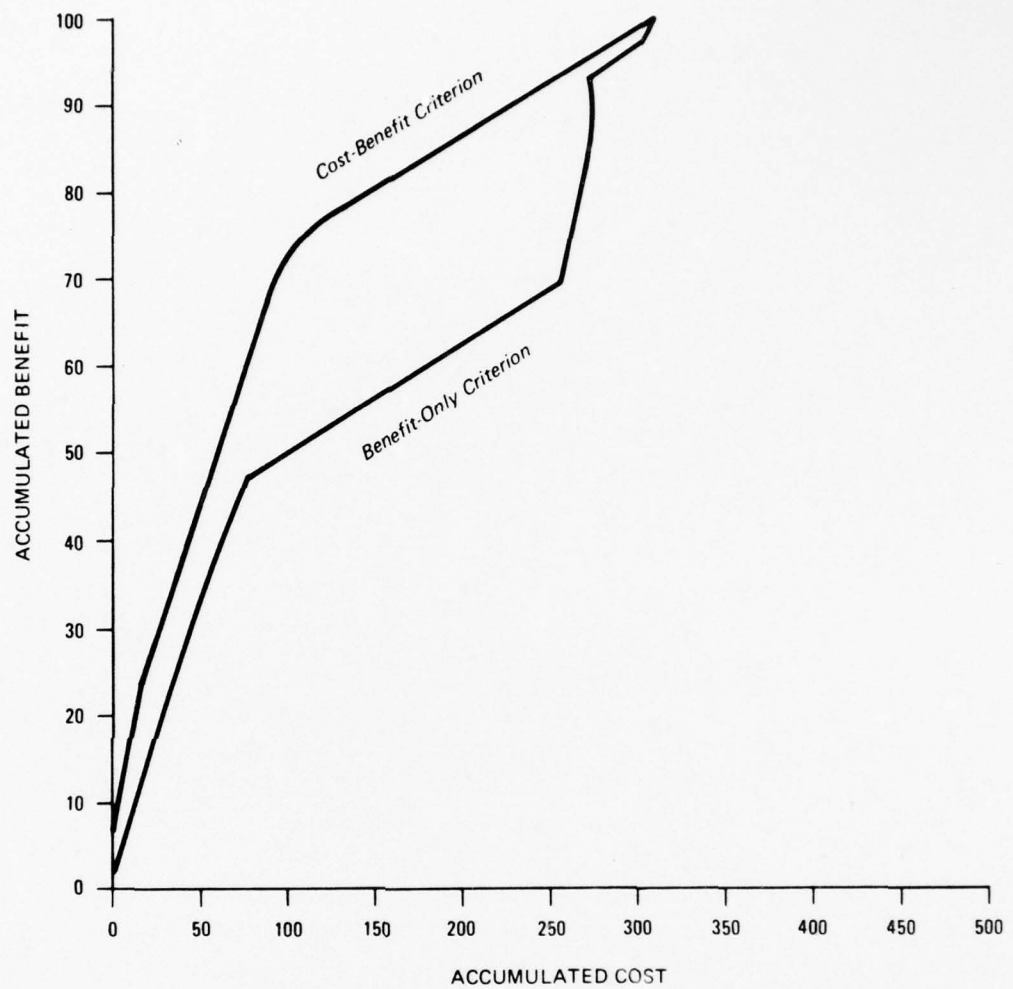


Figure 2-11
FINAL ACCUMULATED BENEFIT VS. ACCUMULATED COST CURVES –
AVIATION SPONSOR

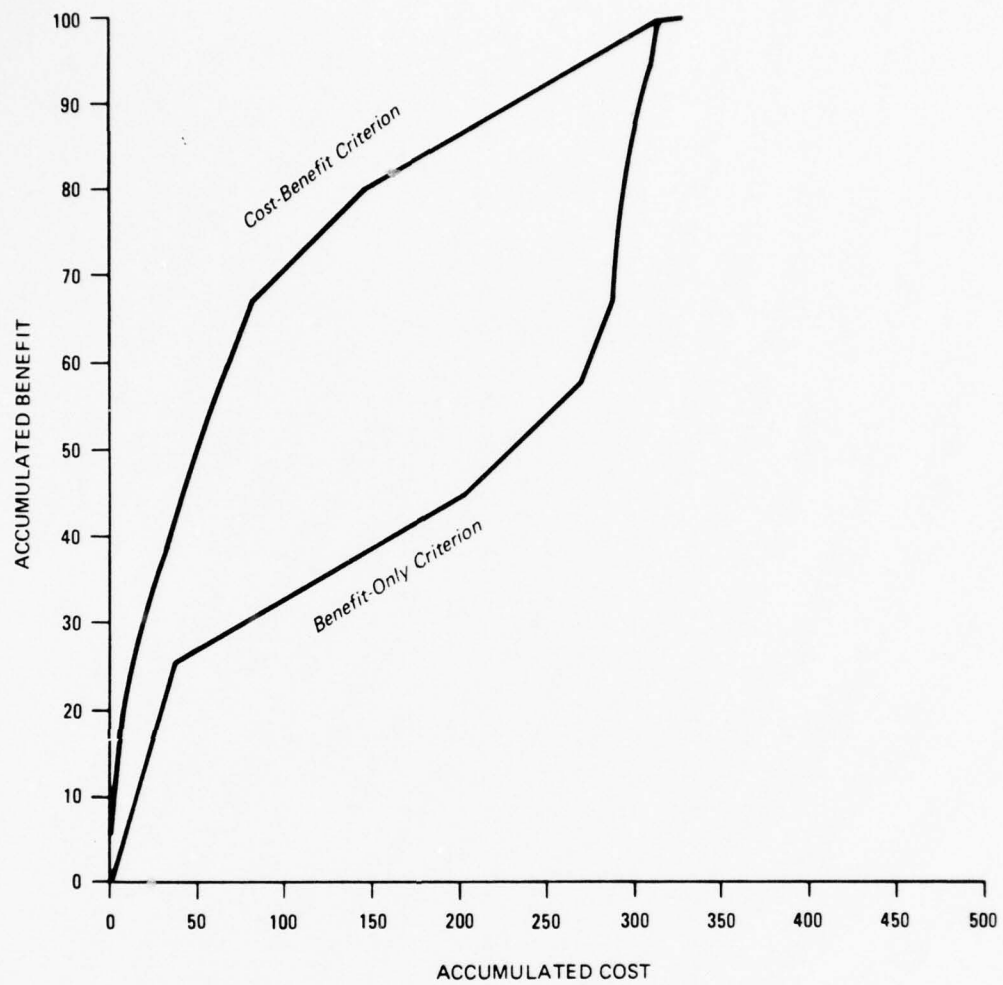


Figure 2-12
FINAL ACCUMULATED BENEFIT VS. ACCUMULATED COST CURVES—
TELECOMMUNICATIONS SPONSOR

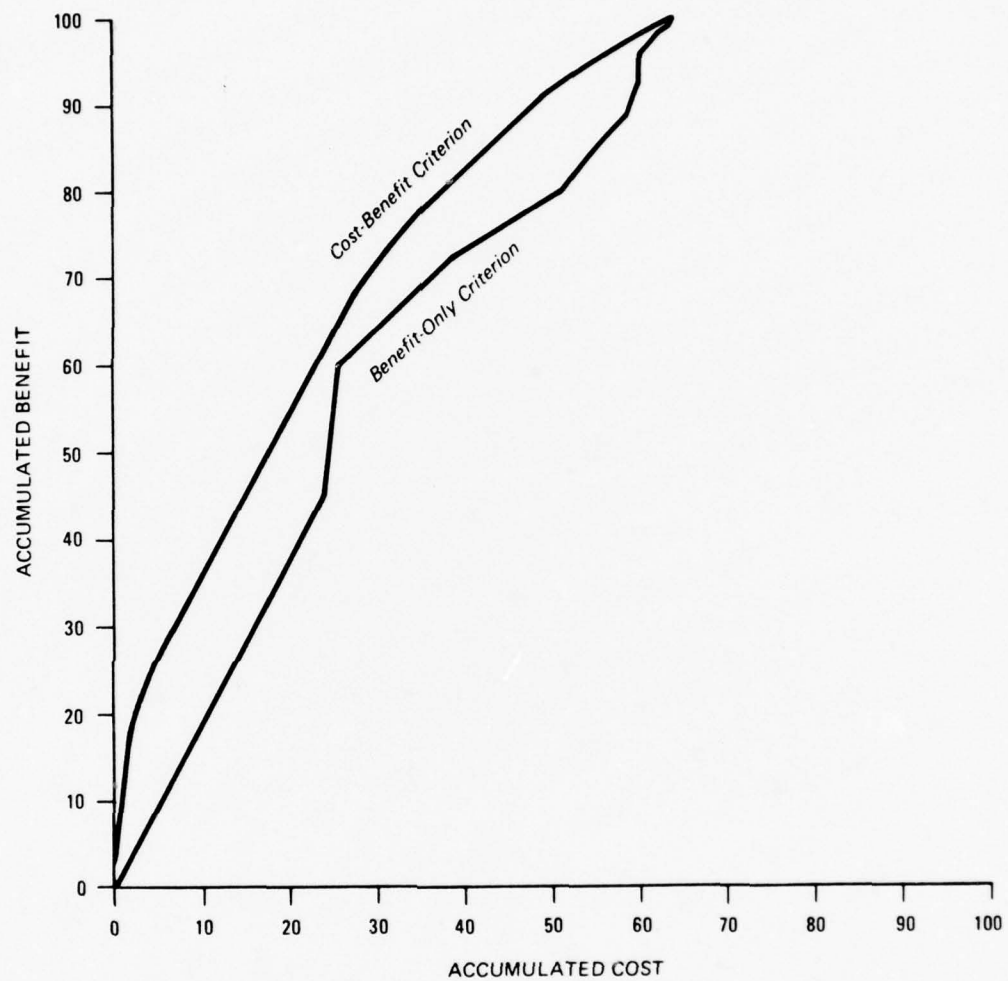


Figure 2-13
FINAL ACCUMULATED BENEFIT VS. ACCUMULATED COST CURVES—
INTELLIGENCE SPONSOR

and the Telecommunications sponsors. The differences between the curves for the Intelligence sponsor fall in the middle.

3.0 ADVANTAGES OF THE COST-BENEFIT APPROACH

The cost-benefit methodology developed for this application should, in theory, lead to better resource allocation decisions if valid benefit and cost information is used. In this application, however, there was considerable (and understandable) disquiet on the part of USMC sponsors as to the validity of available life-cycle cost data. Consequently, the final POM preparation for FY 1979 reflected a benefit-only approach. Action has been initiated, however, to develop an improved cost base for the FY 80 POM cycle in the expectation that better cost data will encourage the use of the cost-benefit approach.

3.1 Justification of POM Recommendations

The systematic assessment process that generated the benefits and produced the cost-benefit ordering of procurements also produced discussions and information that supported and justified the quantifications of benefit. The sponsors used this information to write terse descriptions of the supporting rationale for the benefit numbers assigned to each procurement. These descriptions were used when others asked for clarification of the benefit scale. Additional attributes of this process are its responsiveness to requests for "what-if" analyses, and its adaptability to changes that may occur. The cost-benefit approach itself generates part of this responsiveness and adaptability because the theory dictates how changes are incorporated and what the resultant rankings of prospective procurements are.

3.2 Availability of Interactive Computer Support

An IBM 5100 mini-computer was programmed to do most of the calculations and data storage, retrieval, and manipulation

needed by the working group responsible for preparation of the POM. The software in this computer was interactive in the sense that the officers responsible for POM preparation were able to use it after a very short instructional period without the assistance of a computer programmer. They could make changes to the data and ask for new displays/ printouts at their own convenience without relying on others or waiting in the queues often associated with large computer systems. Their turn-around time was on the order of minutes or hours, and they could take the computer to meetings and briefings with them. This gave the officers a high level of confidence in the output of the computer because they were controlling the inputs and the computer processing themselves.

3.3 Identification of Critical Decision Areas

The cost-benefit approach also facilitated the rapid identification of the real decision points; i.e., that subset of procurements in the "gray area" of the decision-making process quickly surfaced. Consequently, most of the subsequent discussion was focused on the troublesome subset rather than spread evenly across all the procurements. For instance, there were a few procurements that senior officers felt a priori should be funded. However, when the final analysis indicated otherwise, the POM working group was able to show which procurements would then have to be sacrificed to fund them. In all cases, this type of comparison was convincing.

A major decision point for this year's POM surfaced immediately after all of the benefits were assessed and entered into the computer. The expected TOA's for the five-year period 1979-1983 were very uneven, with a minimum in 1980 (Table 1-1). The 1980 TOA had been known for some time, but its impact was not clear. However, both the cost-benefit and benefit-only orderings indicated that there

was a higher rate of expenditure of funds in FY 1980 than in any other fiscal year. Since the Marine Corps does not have a bank available for smoothing out cash-flow problems, this was serious. In fact, a major restructuring of the procurement outlays was required after a short analysis indicated that the rearrangement of a few procurements would not solve the problem. The sponsors were asked to provide several alternative funding profiles for all procurements requiring 1980 funding. Short descriptions of the disadvantages of these alternatives were also provided, including any changes in benefit numbers. The computer software was then used to iterate towards the solution of this problem in a short period of time.

3.4 Education of POM Working Group

In the past, there have been sponsors who were very displeased with the final POM decisions and felt that their procurements were funded at a lower level than optimum. Since the sponsors were uncertain about how much control they had over the outputs of the cost-benefit approach, they were initially skeptical. However, not only were all the sponsors satisfied that the approach had been useful and educational in the end, but those who were in a position to feel shortchanged were satisfied that they had been treated fairly.

Several factors contributed to the sponsors' satisfaction with the cost-benefit approach. First, the logic and recorded rationale for the quantified benefits gave people confidence that all of their inputs were being used. Second, the process of eliciting benefits generated a substantial amount of discussion--discussion that resulted in the education of many more people concerning the pros and cons of each of the procurements. This educational process involved both the

generalists as well as the experts. It gave the sponsors more understanding of each others' programs, which, in turn, resulted in a greater understanding of the decisions that were made.

The Marine Corps programmers responsible for putting the POM together supervised a committee of experts (the sponsors) to complete its job. Committees are necessary when diverse technical information must be digested and summarized. However, it is often difficult to focus committee debates on important topics; they tend to ramble, resulting in a significant waste of time. By using the cost-benefit approach, the supervisors found that they had much more control than usual because they could adjourn the meetings of the committees when the discussion began rambling, analyze several alternatives to the solution of the committee's various problems, and then put a recommendation before the committee for specific comments. This expedience was only possible because of the logic of the cost-benefit approach and the group's direct access to the computer.

3.5 Facilitation of Future POM Efforts

Finally, next year's foundation for the POM is far more complete as a result of this effort. The benefit scales for the programmed future procurements exist although changes resulting from new information and new programs are expected. The rationale documenting these benefit scales with the information used for POM 79 also exists. Consequently, it is expected that the elicitation efforts will be significantly reduced for development of POM 80.

4.0 CONCLUSIONS AND FUTURE WORK

The cost-benefit approach to ranking procurements for future capability has demonstrated utility. It helped to make better decisions, to provide a controlling structure for the decision-making process, and to clarify reasons for the decisions so that programs could be fully justified in the federal review process.

One valuable extension of this work would be to apply the cost-benefit approach to the entire Marine Corps program, that is, to the four types of funding--manpower, operations and maintenance, reserves, and procurement. This would not only systematize and improve the decision-making processes in these areas, but would enable attention to be focused on how the last dollars are being spent in each appropriation. This scrutiny would facilitate the comparison of the relative benefits of these four separate allocations to determine whether it would be advantageous to reallocate funds among them. That is, they would have the detailed logic necessary to decide whether too much money is allocated to procurement and not enough to the operations and maintenance areas.

Another extension of this project effort would be the improvement of the computer software. As DDI's application of this research is expanded and improved, better and more flexible software will be needed to increase the current level of efficiency provided by this new analytic approach.

Although an integral part of the cost-benefit approach is the estimation of life-cycle costs, this was not emphasized in the POM 79 effort. The consensus at the end was that the cost data proved to be the weakest link of the cost-benefit analysis. Therefore, it is essential that both a methodology

and a data base be developed for deriving reliable estimates of life-cycle costs.

Finally, zero-base budgeting is now being implemented throughout the federal government. Until now, the programming of the budget (determination of items to be included in the budget) and the actual preparation of the budget have been somewhat distinct. Zero-base budgeting forces a closer union and requires that the cost-benefit approach be used in choosing among alternatives and determining priorities. It focuses attention on incremental packages of these alternatives. This is exactly the approach used in determining the procurement of future capability items for POM 79; the methodology is a logical instrument for implementation of zero-base budgeting.

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optimal procurements is based upon determination of the "true" costs and benefits of each program. "True" or absolute costs and benefits are often very difficult to determine because subjective estimates must be made, and because some of the less-than-obvious costs and/or benefits may be overlooked.

The programs involved in this analysis were all future capability items in the procurement appropriation. DDI's efforts were focused on obtaining good subjective estimates of the relative benefits for each of these programs. Psychologists and decision analysts have observed that the best way to obtain accurate quantifications of this sort is to use paired comparisons, that is, to ask the expert to make a series of choices between two packages of programs, each choice having certain implications about the benefits of the programs.

The elicitation procedure used for obtaining the benefit estimates was an iterative one. The USMC POM programs were divided into eight categories, each category having a sponsor who was especially knowledgeable about his subset of programs. The elicitation procedure began with an ordinal listing of each sponsor's programs by benefit. Once an initial ratio scale was defined over these programs, the sponsor's responses to choices between numerous sets of programs generated the feedback necessary to modify and improve this ratio scale of benefits.

The next step was to convene a group of "honest-brokers," officers from the Headquarters Staff sections, which do not sponsor any programs. This group was asked to provide a benefit scale for a small subset of all the programs; the subset included one program from each sponsor's list. After the "honest-brokers" had been completely educated about the uses of the programs being considered, the same elicitation procedure--that described above--was used to obtain their benefit scale. This scale provided all of the information needed to collapse the eight distinct sponsor benefit scales into one.

This cross-sponsor elicitation of benefits provided a proper scoring rule. The meaning of the proper scoring rule was explained to each sponsor in the course of eliciting his benefits: If the sponsor ranked the lower-benefit procurements too high on his benefit scale, the cross-sponsor weighting would drag all of his high-benefit procurements down in relation to those of the other sponsors. A proper scoring rule for subjective elicitations of this sort thus motivates the sponsors to provide their "true" beliefs in order to maximize their final position in the resource allocation. Finally, each sponsor and the "honest-brokers" wrote concise justifications of their respective benefit scales. These justifications were used for briefing the POM recommendations.

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